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Flash ignition and initiation of explosives-nanotubes mixture

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The recent astounding discoveries of ignition in single-walled carbon nanotubes (SWNTs) after exposure to an ordinary photographic flash, *(1)* other formulations of carbons containing noble metals, *(2)* and polyaniline nanofibers *(3)* prompted us to explore a possible further instigation of explosive materials. Here, we report that an ignition and initiation process, further leading to actual detonation, does occur for explosives in lax contact with carbon nanotubes that are prone to opto-thermal activity via a conventional flashbulb. Optical ignition and initiation of explosives could thus far only be accomplished through lasers, *(4)* with specific characteristic of high power, pulse length, wavelength, and a small target area that greatly inhibit their applications. Our results have the implication that explosives with opto-thermally active SWNTs formulations are new ideal candidates for remote optical triggering of safety apparatus such as the firing of bolts on space shuttles rockets and aircraft exit doors, and for controlled burning of explosives as actuators.

Ignition in an explosive target can be achieved by applying a thermal stimulus that causes local burning at a particular site. Initiation is achieved once the local burning accelerates into a violent reaction with the formation of a shock front and the rapid build-up to detonation. We flashed several samples with various combinations of the explosive PETN (pentaerythritol tetranitrate) and SWNTs similar to that used by Ajayan et al. *(1)*. Ignition and burning proceeded with bright illumination and glow (Fig.1 A) compared to a control sample of only SWNTs. Large photoacoustic effects were observed in all flashed samples, while samples compacted to higher densities ignited less brilliantly. Based on weight measurements, PETN was completely burned in all experiments, while the SWNTs lost a third of its mass during the burning process.

Efficient heat transfer from the ignited nanotubes to relatively large crystallites of PETN (~5 micron in diameter, Fig.1B) is key to the explosive's ignition. From the observed structural reconstruction of flashed SWNTs, local temperatures were estimated to be in the range of 1500-2000 °C. *(1)* Several studies showed that the thermal conductivity of nanotubes are very high. *(5-7)* These two factors account for the observed rapid ignition and burning of the explosive materials placed on the bottom of SWNTs. At the microscopic level, vast empty regions separate the PETN crystallites and the nanotubes. However, the absorbing particles in the nanotubes are the natural hot sites of reactions, the counterparts of local zones of high temperatures known as hot spots, whose growth and interaction is essential for ignition and initiation of explosives. *(8)*

We loaded 30 grams of K-6, a cyclic dinitrourea explosive *(9)*, into an 8 inch copper cylinder with _ inch internal diameter, and attached it to a 2 inch diameter copper funnel with a 1/8 inch diameter orifice at one end, and to a witness plate at the other. Loosely packed SWNTs (0.020g) were added on top of the K-6. We placed pins that measure the arrival time of the shock wave at selected intervals on the cylinder (Fig. 1C). A flash bulb was installed 5 cm above the funnel containing SWNTs and K-6. Flashing resulted in initial deflagration of K-6 for approximately 1.5 minutes followed by a detonation (Fig. 1D). Analysis showed a shock wave with an average speed of 6.8 km/sec has ensued upon reflection from the witness plate, a phenomenon known as retonation. *(10)*

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Figure 1 (A) Burning of a 10 mg sample of SWNT placed on top of 10 mg of PETN upon irradiation.

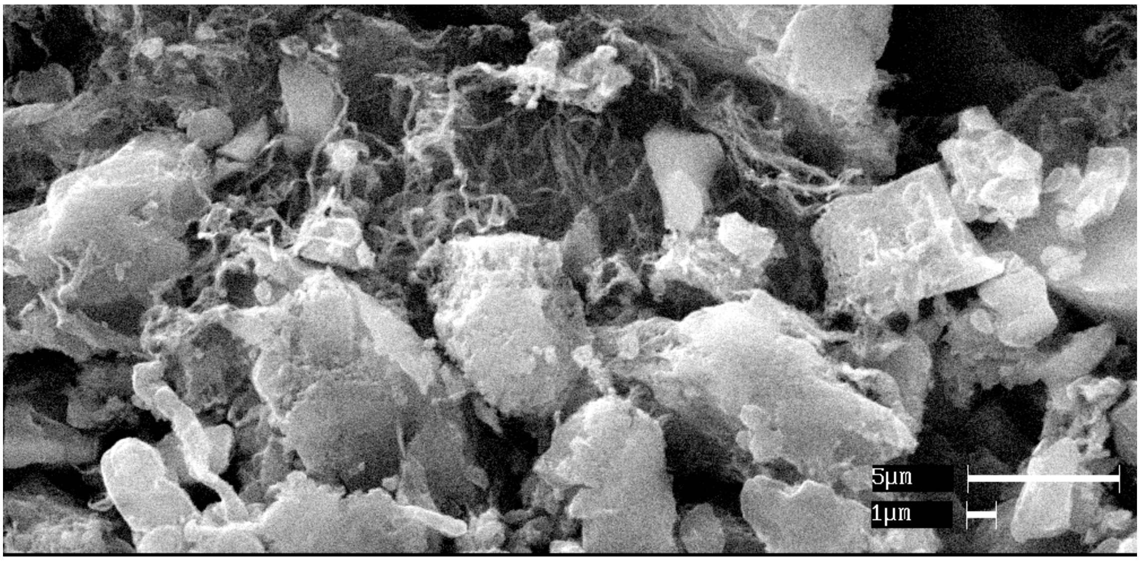

Figure 1(B) SEM image showing micron size PETN grains among SWNTs.

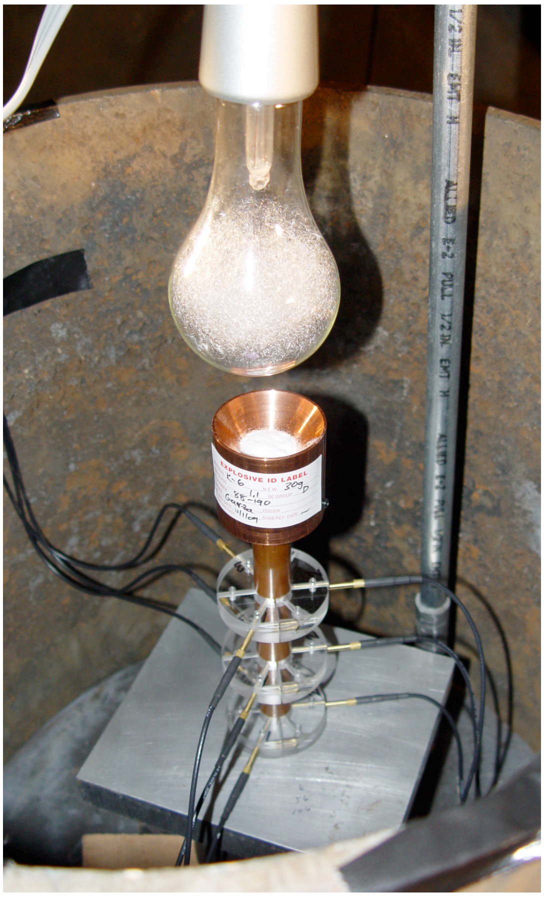

Figure 1 (C) Assembly of copper cylinder and funnel containing K-6 explosive prior to addition of 0.020g SWNTs and irradiation with the flashbulb.

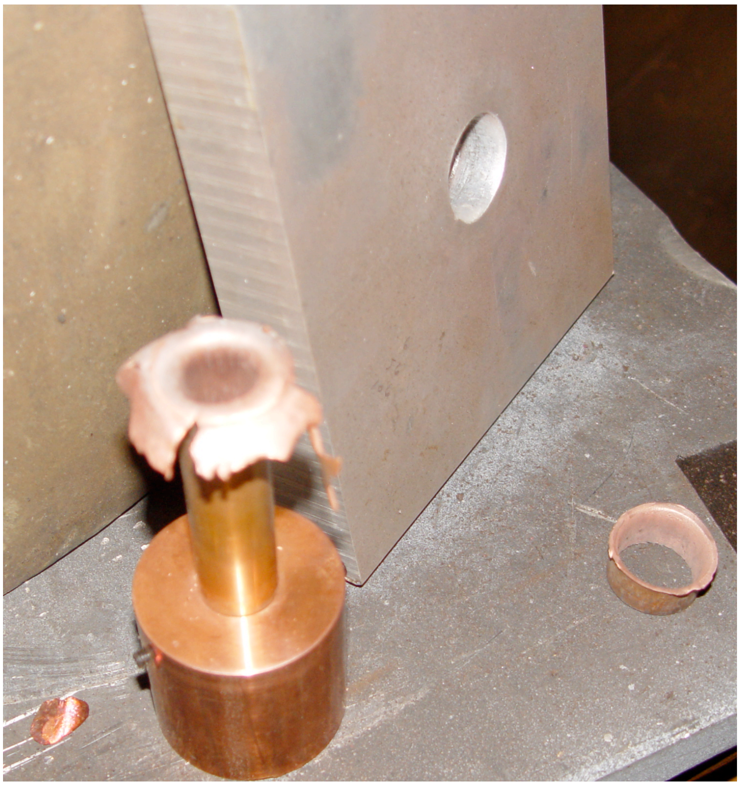

Figure 1 (D). Assembly after detonation showing Cu cylinder, funnel and witness plate.